REMOTE SENSING IMPLICATIONS OF CHANGES IN PHYSIOLOGIC STRUCTURE AND FUNCTION OF FOREST TREES

Charles E. Olson Jr.

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Charles E. Olson, Jr.

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Project Director

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INTRODUCTION

Early detection of insect and disease attacks is one of the keys to preventing epidemic conditions. In the early stages, infestations of many organisms are difficult to detect and rapid surveys of large areas are virtually impossible using ground techniques. Aerial survey techniques are rapid and permit coverage of large areas at relatively low cost. Recent advances in aerial reconnaissance techniques, particularly in simultaneous recording of several spectral bands (i.e., bands differing in wavelength recorded), appear to provide a more potent detection system.

Many insect and disease attacks produce a disruption of the water metabolism of host trees by plugging or severing of the water and solute conducting tissues. Trees subjected to such attacks become less vigorous and their foliage develops higher moisture tensions than unaffected trees. Since reduced vigor and increasing moisture stress are found in trees subjected to drought as well as in trees attacked by a number of organisms, these symptoms do not necessarily indicate the presence of an insect or disease attack. It seems likely that at least some of the past, unsuccessful attempts at aerial inventory of insect and disease conditions did not achieve their full potential because of inadequate understanding of the basic patterns of change in reflectance and emission from tree foliage and the factors producing such changes.

This report describes part of a continuing study of physiologic factors affecting reflectance and emission characteristics of tree foliage. Previous work (Weber and Olson, 1967) discusses changes in pine and broad-leaved trees subjected to moisture stress through controlled watering. Late in 1967 this work was expanded to include

consideration of the effects of salt accumulation on the reflectance and emittance characteristics of tree foliage.

OBJECTIVES

The current work was designed to provide information bearing on the following questions.

(1) Does salt accumulation alter the reflectance properties of foliage?

(2) If salt accumulation does affect reflectance properties, are the changes continuously progressive or is there a threshold level at which changes first become noticeable?

(3) If changes in reflectance properties are observed, do these changes result from increased moisture stress similar to drouth, osmotic action, or blockage of vessels in the xylem tissues?

(4) Does exposure to high salinity increase susceptibility to Verticillium wilt infection?

PILOT STUDY

Preliminary studies of the salt tolerance of several tree species to $CaCl_2$ and NaCl were conducted to aid in design of more detailed studies. One to three year old seedlings of quaking aspen (*Populus tremuloides*), tulip poplar (*Liriodendron tulipifera*), red oak (*Quercus rubra*), black oak (*Q. velutina*), willow (*Salix* sp.), and sugar maple (*Acer saccharum*) were used. All sugar maple seedlings were collected from natural reproduction in the Ottawa National Forest in Iron County, Michigan. All other seedlings were grown in the University of Michigan greenhouses for other studies completed previously. Early in January, 1968, all plants were placed in four inch pots containing a soil mixture consisting of one part sand, one part screened peat, and two

parts loam. Mean oven-dry weight of the soil in the pots was 477.38 grams, plus or minus 20 grams.

After potting, the seedlings were kept in the greenhouse under artifical lighting to bring them out of dormancy and maintain growth. Measured amounts of salt were applied to the surface of the soil in the pots to give concentrations of 100, 1,000, 10,000, and 100,000 parts of salt per million parts of soil. The salt was carried into the soil by downward percolation of distilled water applied regularly to the soil/salt surface. A summary of the salt treatments is shown in Table I.

Initial salt applications were made on January 12, 1968. By January 17, foliage on plants treated with 100,000 parts per million was severely wilted, discolored, and quite brittle, but there was little evidence of marginal burning. Tulip poplar receiving the 10,000 parts per million treatment showed some discoloration in the vein areas and the leaves had begun to wilt. The 10,000 parts per million treatment of aspen produced less yellowing and the leaves were not wilted, although marginal burning was evident.

On March 4, 1968, a second application of $CaCl_2$ was made to the oak, willow, and maple seedlings using the same concentrations as in the first application, except that the 100,000 parts per million treatment was omitted. An additional group of maple were treated with NaCl in the same concentrations as with $CaCl_2$. The first spectral reflectance curves were obtained on March 15 and additional curves obtained at weekly intervals through March 29, 1968. In all cases reflectance measurements were made without removing the leaves from the seedlings. After a reflectance curve had been obtained, the leaf was removed and placed in a fixing solution preparatory to microscopic examination of the leaf tissues. Leaves picked for microscopic

Table I. Summary of the species, type and concentrations of salt used during a pilot study on the effect of salt uptake on light reflectance properties of tree foliage conducted in 1968.

Date Treated	Jan. 12	Jan. 12	March 4	March 4	March 4	March 4
Species	Tulip pop.	Aspen	Oak	Willow	Maple	Maple
Salt Used	$CaCl_2$	$CaCl_2$	$CaCl_2$	$CaCl_2$	$CaCl_2$	$NaCl_2$
None	x	x	x	x	x	x
100 ppm	x	x	x	x	x	x
1,000 ppm	x	x	x	x	x	x
10,000 ppm	x	x	x	x	x	x
100,000 ppm	x	x				

examination were placed in a fixing solution made up of 75% Chromic Acid-1%, 5% Glacial Acetic Acid, and 20% Formaldehyde-40% Aqueous. Leaves were placed in individual screw top vials just large enough to accommodate single leaves, and covered with fixing solution, and sealed with masking tape. Microscopic examinations of these materials have not yet been completed. By March 29, all trees treated with 10,000 parts of salt per million parts of soil showed severe burning, discoloration, and wilting of the foliage. Of those treated with 1,000 parts per million, the oak appeared least affected with slight burning of the spines and tips of lobes, while willow was least tolerant and there was discoloration over entire leaves. The maple foliage was also damaged extensively; however, damage did not appear as severe as in willow. Comparison of the sugar maple seedlings treated with NaCl and $CaCl_2$ indicates no difference in visual appearance or in the reflectance curves, suggesting that under present test conditions there is no significant difference in toxicity of the salts to the seedlings. Based on data now available oak appears to be more resistant to the chloride salts than all other species tested. Aspen, tulip poplar, maple, and willow showed decreasing tolerance to the salt, in that order.

THE CURRENT STUDY

Following the pilot study, two hundred sugar maple seedlings (9 to 15 inches tall) were purchased from the Forest Nursery Company of McMinnville, Tennessee. These seedlings were placed in five inch pots containing uniform volumes of the soil mixture previously described. The total number of trees was divided into two groups, one for subjection to drought conditions by withholding water and the second for salt treatment.

A. Drought

The group of trees selected for the drought treatment was divided into two sections. In one section the young trees had leafed out during the previous week, while in the other they leafed out shortly after the treatment began. In each section half the trees are being watered twice weekly with 150 ml of distilled water, and the other half are receiving 150 ml of distilled water once a week. Twice weekly, photographic impressions of selected leaves are being made for leaf area determination, and the length of the lamina and petiole on newly formed and expanding leaves are being measured. The rate of stem extension on the new seasons growth is also being measured. A control group of plants is being watered adequately every day with distilled water. Measurements of leaf area and lamina length, and petiole and stem extension are being made twice weekly on these plants.

Light reflectance measurements (0.5 to 2.6 micrometers) are being made at regular intervals on selected trees from each treatment group. Repeated reflectance measurements will be made on the same leaves on each plant over a period of two months. At the end of this period these leaves will be removed from the seedlings, their moisture tension determined in a Scholander pressure cell, and the leaves prepared for microscopic examination of selected cross sections.

B. Salinity

Trees assigned to the salinity test were randomly divided into twenty groups of seven trees each. Ten groups were treated with NaCl and ten groups with $CaCl_2$. In each group trees were randomly assigned to one of seven salt concentration treatments. Concentrations of 0.0, 0.05, 0.10, 0.25, 0.50, 1.0, and 2.0 per cent salt (by weight) in distilled water are being used. During the initial salt application, each

plant was watered to excess with the appropriate solution and allowed to drain. Each pot was placed on a plastic saucer, and any further liquid that drained out was discarded. Thereafter, each pot was watered regularly with a sufficient amount of distilled water to allow a little to drain out into the saucer. This liquid was placed back in the pot a few hours later. This procedure is being continued and by this means the concentration of salt in the soil solution is kept as constant as possible. Since each pot is maintained at field capacity, any moisture tension developing in the leaves should not be the result of insufficient water.

Throughout the experiment, measurements of the length of the new seasons stem and petiole extension, and leaf area and lamina length will be made on selected leaves on each seedling. Reflectance measurements will be made on each of these leaves at regular intervals. Selected leaves will be prepared for microscopic examination.

FUTURE WORK

At the conclusion of the salinity test five groups of trees from each salt treatment will be repotted into soil containing the Verticillium wilt fungus, to see whether exposure to saline conditions has increased the susceptibility of sugar maple to this disease. Further reflectance measurements will be made on selected leaves during this treatment. After the final reflectance measurements, these leaves will be removed, their moisture tension ascertained, and their anatomy studied.

At the time the groups of trees from the saline treatments are exposed to the Verticillium wilt, a group of healthy trees which have not been subjected to the salt treatment will be actively infected

(by mechanical injury to roots during repotting) with this fungus. The progress of these trees will be measured in terms of further extension of new seasons stems and petioles, increase in leaf length and leaf area, changes in leaf reflectance, and finally, moisture tension and leaf anatomy.

LITERATURE CITED

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